SEMI - ANNUAL REPORT No. III - NsG - 362

1 February 1964 - 1 August 1964

OBSERVATORY—ERECTED 1843

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SEMI- ANNUAL STATUS REPORT NO. 3 ON SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES

WORK DONE UNDER NASA GRANT
NsG - 362

February 1, 1964 to August 1, 1964

PREPARED BY:

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WASHINGTON 7, D.C.

SEMI - ANNUAL STATUS REPORT NO. 3 TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

"SPECTROSCOPIC STUDY OF SOLAR AND PLANETARY ATMOSPHERES"

NAME AND ADDRESS OF INSTITUTION: GEORGETOWN UNIVERSITY
WASHINGTON 7, D.C.

PROJECT DIRECTOR: Dr. Francis J. Heyden, S.J.

ASSISTANT SCIENTIFIC DIRECTOR: Dr. Carl C. Kiess

1. Work done: Following the pattern of the previous reports, the first area of this report is simulated Martian Atmospheres. Area three is, however, in this report, included in area two due to the similarities in the reduction and analysis of the spectra. The third area in this report deals with the use of the Photoelectric Spectrum scanner.

During the summer months the Observatory carries on a program which has resulted in dual benefits. High school seniors and college students of proven ability or interest in science are employed as assistants with the various project directors. The results have completely justified the experiment. The students have developed an understanding of the factors involved in research by direct participation. The opportunity to assist a working scientist has strengthened their interest and in several cases given more definite career impetus. The preceptors have found the work of the students most helpful. The time spent in training was compensated for by the assistance rendered once the student had acquired the necessary skills. The latter part of the first year of the students' service was productive, the second year the student returned he became from the first day a contributing member of the project team.

Three such students have been selected: George Bullen from Fordham University; Charles Roesle from the University of Maryland; and Ellis Holdenried from Georgetown University.

Area 1. Laboratory Spectra - Simulated Martian Atmosphere.
The absorption bands of nitrogen peroxide have been mapped with high dispersion (4.95 A/mm.) through the region: 3300 A to 6600 A. The white light source used for this mapping was a G.E. 30 amperes tungsten ribbon strip lamp standard of spectral radiance, as described in the Journal of Research of the National Bureau of Standards, Vol. 64 A, No. 4, and our semi-annual report No. 2.

The Nitrogen peroxide sample from which the spectral mapping was made is equivalent to a path-length of 2.7 mm.-atmospheres at 0°C, produced in the following manner: Nitrogen peroxide was admitted into an optical tube at a pressure of 2 mm at 25°C, using the vacuum apparatus described in our semi-annual Report No. 1. A vacuum of .0001 mm previously obtained in the tube guarantees residual air less than 1 part in 20,000. At 25°C, Nitrogen peroxide at a measured total pressure of 2 mm. contains NO_2 at a partial pressure of 1.98 mm, and N_2O_4 at a partial pressure of .02 mm. At 0°C, NO_2 makes up approximately 76% of the NO_2-N_2O_4 mixture, producing a calculated partial pressure of 1.73 mm of NO_2, or an equivalent path-length of 2.7 mm-atmospheres in an optical tube of 1 meter in length.

Thirty-eight plates have been exposed covering the region from 3300 A to 6600 A, as proposed in Area I, No. 1 of our Report of Feb. 1, 1964. Nine of the most revealing plates cover the region as follows:

Plate No.	Region	Plate No.	Region
D 1274 75	3200A - 3734A	D1274 81	4736A - 5270A
73	3306A - 4045A	80	4890A - 5430A
68	4045A - 4470A	70	5328A - 6136A
67	4383A - 4891A	79	5880A - 6677A
64	4528A - 5110A		

Prints of four plates covering this region are included in this report. The scale of prints to plates is 6 to 1, therefore the prints have a dispersion of 1.95A/mm. Four exposures of varying time length bring out NO_2 absorption features in successive regions across each print. An Iron Arc spectrum is included on each print for wavelength calibration. An exposure to white light, without NO_2 absorption features, is included on each print showing the variation of the light source intensity and the plate response to decreasing wavelength. Heavy absorptinn features of NO_2, and generally increasing absorption toward shorter wavelength can be clearly observed in these prints.

A path-length of 2-3 mm- atmospheres was chosen for this initial mapping of the NO_2 absorption spectrum because this pressure, while low, shows the absorption features quite clearly from exposure times of reasonable lengths. During this phase of the work, a detailed knowledge of NO_2 absorption features was sought, and a precise knowledge of pathlength was not of utmost importance. Thus, pressures at low temperatures were calculated from pressure readings at 25°C, as mentioned above.

However, in the present phase, producing NO_2 absorption spectra with a sunlight source for direct comparison with spectral plates made of the Martian atmosphere, a more exact knowledge of the pathlength will become necessary. For this reason, experiments are being made to adapt a thermocouple pressure gauge directly to the optical tube so that pressure may be read directly from the tube while it is disconnected from the vacuum system and being exposed to temperature changes and photo-disassociation in sunlight.

Area II. Observations.

In the period covered by the report Jupiter and Mars were not observable. Three sets of observations of Venus were attempted, two for rotational velocity determination and one for the violet "fall off."

Different attempts at measuring the rotational period of Venus have yielded widely separated results. Some observers find a long period, possibly synchronous with the sidereal period. Others find the period to be on the order of our own rotational period. The high dark side temperature would seem to indicate a short period. It may be argued that a greenhouse effect causes the high temperature, but proponents of this theory have not satisfactorily explained the absorption in the violet region. The Georgetown observations will provide an insight into both aspects of this problem.

For the rotational observations a large image size was desired so the exterior optics of the spectrograph were changed from the fifteen foot focal length arrangement to the fifty foot focal length arrangement. This provides an image of Venus about 4 mm. high.

The first series of observations were made in May when Venus was in the evening sky. The Gale grating of 30,000 lines per inch was used to obtain the highest possible dispersion. In July, when Venus was in the morning sky, the Rowland grating of 20,000 lines per inch was used. The Rowland grating has a dispersion of 3.5 A/mm as compared with 2.1 A/mm for the Gale grating. Less time was abailable for exposures in July so the lower dispersion was a necessary compromise to obtain the needed speed.

The first series was highly successful. Eight sets of plates (two of 103aF and one 103aD) were obtained but only one plate was obtained in the second due to inclement weather.

The sun was taken for comparison purposes. The observations covered the 6900 A to 5000 A region, but the 6600 A - 6300 A is the important region for this purpose. As it contains many telluric lines as internal standards.

The guiding technique is a critical factor in these observations. If the axis of rotation is assumed to be parallel to the line of the cusps, the maximum Doppler shift will occur if the limb of the planet is kept on the slit. In practice this is quite difficult. Due to the low altitude of Venus and the inaccuracies which are inherent in the sidereostat arrangement, the image of the planet is constantly in motion across the slit. The guiding was done by two observers, R.E. Murphy and

Mrs. H. K. Kiess. The pattern of guiding of each observer has been recorded and the proportion of time each guided has been noted. P 193 taken May 21 shows a tilt in the reflected solar lines, but not in the telluric lines. Unfortunately this result could not be reproduced and the orientation of the slit found. A possible explanation of this tilt may lie in the fact that an unusually large drop in temperature occurred that evening. No mechanism by which this could be accomplished is known. However the correlation should be noted.

Two new observations were made of the planet Venus for the determination of fall off in the violet relative to the sun. More observations are to be made in late August when the moon is in a favorable position and of sufficient brightness for proper comparison.

The first observation was hampered by intermittent clouds and is underexposed. The second is also underexposed, and cannot be microphotometered. Visual inspection of the hour long exposure of Venus shows it to be denser than the hour long lunar exposure at the long wavelength limit (about 4800 A) but less dense at the H and K lines (about 3900 A). Other plates aken in the period covered by the previous report show this same effect.

For the fall off work the exterior optics were changed back to the fifteen foot focal length arrangement.

The guide hut of the spectrograph has recently been enlarged to permit greater flexibility. Not only does this make room for the direct reading scanner equipment, but also artificial comparison sources can now be used with much greater ease.

Future observations include the previously mentioned program on Venus as well as continued regular observations of Jupiter. The Wood grating will be used in conjunction with the fifteen foot optics.

Reductions of Spectral Observations . A great deal of time and effort has been spent on improving reduction techniques. What is being sought is a fast, accurate and inexpensive method of analyzing planetary spectra. The method of data acquisition has been determined, and except for small variations as will be explained, should be in its final form. Interpretation of the significance of the data will necessarily have to await the perfection of the acquisition technique and the accumulation of data.

In addition to analyzing the planetary spectra, a new approach to the determination of Venus' rotational velocity has been developed.

As mentioned in the last report, the linear differences method of spectral analysis is no longer being used. Areas under the microphotometer curve are measured and the ratio of the areas of planetary and solar spectra are considered.

If T is the transmission,
$$\frac{T_2}{T_1} = \left(\frac{I_1 t_1}{I_2 t_2}\right)^{\gamma}$$

and the ratio of the transmissions of solar to planetary spectra should remain constant if γ remains constant there are no reciprocity failure or saturation effects and there is no planetary absorption. Since all of these factors are easily determined except the planetary absorption, their effects may be removed and the resultant variation will be due to planetary absorption. The areas represent an integration of the transmission.

Thus, when perfected, this approach will provide a quick accurate and inexpensive method of studying planetary spectra. Correlation with laboratory data will be rapid as well. Band envelope shapes should be readily determined as well as the presence of new bands and variations in the strength of absorptions. With the added benefit of a long series of regular observations, much can be gained from this study.

A number of different approaches have been tried along this line. One plate (1274-27) of Jupiter and the sun has been selected for this study. A scale measurement of microphotometer tracings of this plate was made of Jupiter's spectrum and that of the sun. Every 0.6 A was measured and plotted, with care taken to assure that equivalent regions were measured on both tracings. Their ratio was also plotted as was the smoothed ratio (using a ten point running average.) The region selected (5400 A to 5700A) includes a known band as well as a possible new one. Examination of figures 3 and 4 show that the 5430 A band is clearly shown although it is a weak one. The feature at 5580 A may be present. It appears to be, but further refinement of the technique is needed, and other tracings must be examined.

The scale measurement is tedious and very time consuming. The use of the Telereadex, a projection measuring engine, increases both the speed and the accuracy. A trapezoidal approximation is used to find the areas.

Different intervals have been tried, ranging from 5 A to irregular ones, as determined by the spectral features (i.e. every line is computed separately). The computer may determine regular intervals as it goes or it may be instructed on the tape with the measurements. In this manner a tape made for one kind of interval may be used for another. An interval of 2 A appears to be satisfactory for initial examination. Smaller intervals would be desired for the determination of a band envelope. Figure 5 shows the region near the 5430 A band of Jupiter with 2 A intervals.

A criterion must be established whereby noise can be distinguished from actual absorption. Repetition of a feature on several plates should provide the answer. A study of the contribution of lines broadened in the planetary spectrum will be made. Due to the longer exposure the lines are broader and therefore will alter the ratio. A series of lunar exposures with an aperture stop for the parabolic mirror will be made this fall for that purpose.

Analysis of the Venus plates for Doppler shift due to rotation is in progress. A plate was measured using a conventional measuring engine and the wavelength calculated using a least squares solution with ten I. A. U. standards for each region. The results were unsatisfactory so a new approach is being tried. Very accurate measurements are required in this work and a careful recording of faint lines must be made. It has been found that measurements can be made on microphotometer tracings with a higher degree of precision and more faint lines may be seen. Even an untrained observer can measure many very faint lines.

Each plate is used to make two microphotometer tracings. The plate carriage drive is reversed after the first and the plate raised slightly so that the microphotometer scans a different section of the plate. In this manner noise effects are eliminated. Figure 6 shows two runs of a spectrum (without reversing the plate carriage drive here). Note the large number of small features which appear both times.

The dispersion on the tracings is about 2 A per inch. Measurements are made on the Telereadex. Only 12 A intervals may be measured at a time so it is necessary to use standards which are not as well determined as the I. A. U. standards are. For this purpose the Revised Rowland Tables were originally used. The unpublished thesis (1964) of Dr. Ahmad Kiasat is currently being used for this purpose. A linear interpolation between two known standards is being used.

The Doppler shift will be about 0.24 A at 6500 A for the observations of May, 1964. This corresponds to a velocity of -11.10 km./sec. The velocity consists of the velocity due to the earth's rotation at this latitude, the relative velocity of the earth and Venus and the Venus velocity with respect to the sun. Figure 7 indicates the effect of Doppler shift. Preliminary results indicate a slow retrograde motion but many factors are not yet accounted for an no estimate of the error is possible.

Variations in the speed of the paper transport of the Brown recorder, and in the plate carriage drive must be determined. The Brown recorder error is probably very slight, but the error in the drive of the plate carriage is certainly of significance. A preliminary check of the dispersion shows that this is true. When all of the plates have been measured an assessment of the errors involved will be made.

Area III. Photoelectric Spectrum Scanner.

The Photoelectric Spectrum Scanner was manufactured by Electro-Optical Systems Inc. of Pasadena California. It was originally shipped to Georgetown Observatory on March 2, 1964. It arrived in a damaged condition and was returned. It has now been placed in operation.

The Scanner consists of the following items:

1) Chopper - The chopper consists of a constant speed (3600' rpm) 115 volt A. C. motor manufactured by the Minarik Electric Co., and a 12 blade chopper wheel.

2) Detector Unit - The detector unit is mounted in a carriage which contains spring loaded rollers which the unit to be attached between the rails of the Georgetown Observatory Wadsworth Mountings.

3) Preamplifier - The preamplifier is connected to the detector unit by a short cord, and can be mounted on the detector unit so that both can move simultaneously along the rails.

The preamplifier is connected by a detachable cord to the amplifier.

4) Amplifier - The amplifier is provided with four controls:

a) Power control on/off switch.
b) Three position time constant switch which permits the choice of time constants of zero, 0.1 second, or variable from 0.1 to 10 seconds.
c) A bias or zero adjustment knob.
d) A "Fine T" control for varying the time constant from 0.1 to 10 seconds.

5) A Rectiriter recorder manufactured by Texas Instruments of Houston, Texas. The recorder is attached to the output of the amplifier.

6) Four fixed width slits plus one dark slide which fit over the entrance to the scanner. The widths of these slits and the band width using a 30,000 line per inch grating, are given below:

Slit no.	Microns	Band width A
1	158	0.40
2	304	0.76
3	572 - 766	1.43 - 1.92
4	1048	2.62

An example of the operation of the scanner is shown in the figure 8. The scanner was set on H_α using slit 2 and the 30,000 line per inch grating. The sun was permitted to drift by the entrance slit. It should be noted that the limb tracings are not symmetrical as is often observed in this type of observation. The scans were very reproducible even to the smallest of features.

It was found that the instrument can be focused on H_α by observing the deflection of the Recorder. The accuracy of focusing by this method was $\pm$ 0.10 inches with an 11 foot focal length. This would indicate that focusing in the infrared will be no problem.

It will be highly desirable to develop a drive motor in order to scan objects through a range of wavelengths. It is anticipated that this modification will be utilized after initial feasibility tests are completed.

Due to conflicting programs, poor seeing and unfavorable position of the planets, these objects have not been observed. It is anticipated that they will be observed during the month of August. However, it may be necessary to modify the scanner in order to make such observations possible under such high dispersion.

Personnel in Grant:

Dr. Francis J. Heyden, S.J. Project Director

Dr. Carl C. Kiess, Assistant Project Director

Dr. Whiting Willauer, Postdoctoral Fellow (Georgetown Univer

Graduate Student Assistants:

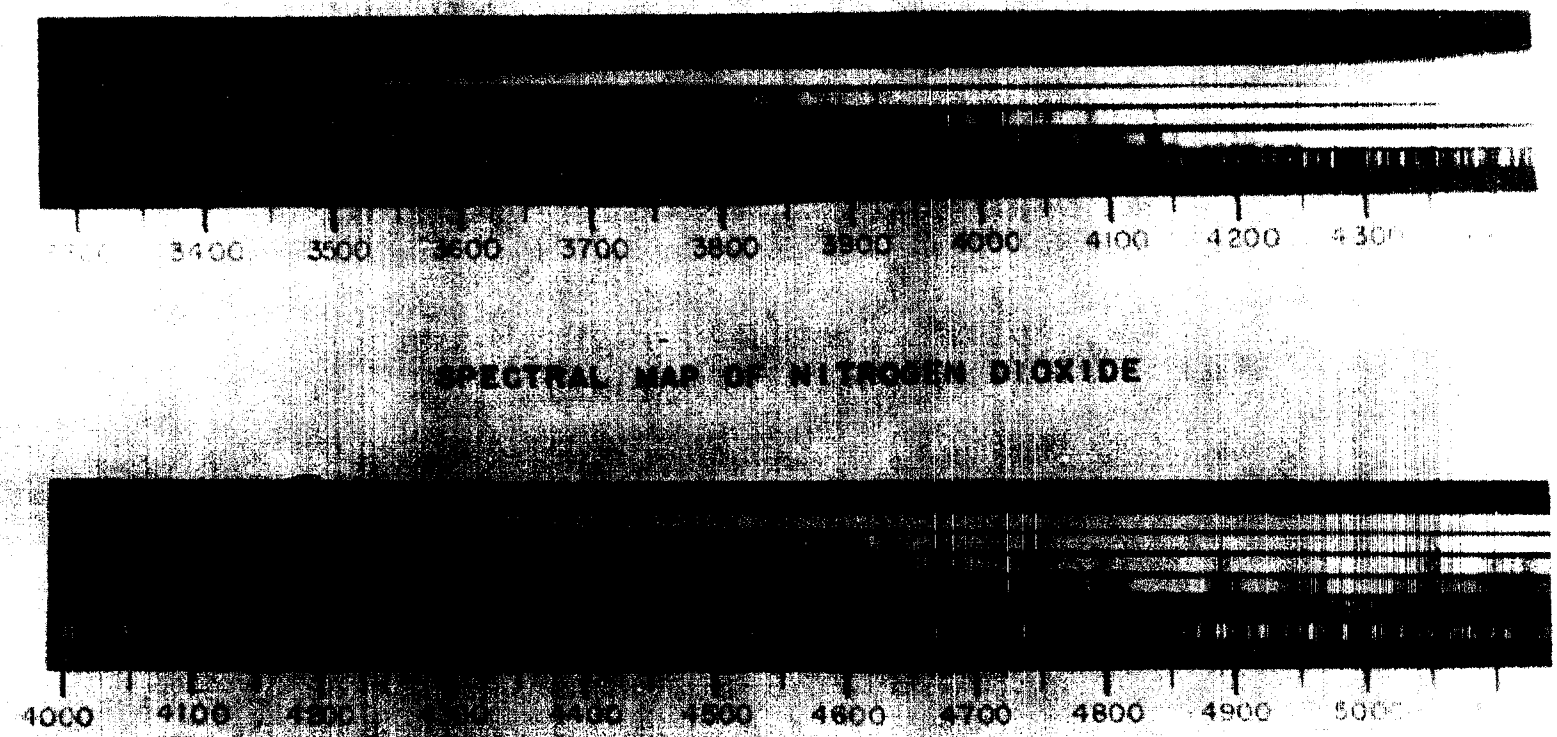
Mr. Robert Murphy
Fr. James O'Brien, S.J.

Summer Program Students:

Mr. George Bullen
Mr. Ellis Holdenried
Mr. Charles Roesle

Financial Report:

cf. University and Nonprofit Institution Financial Management Report (forwarded by University Treasurer's Office)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SPECTRAL MAP OF NITROGEN DIOXIDE
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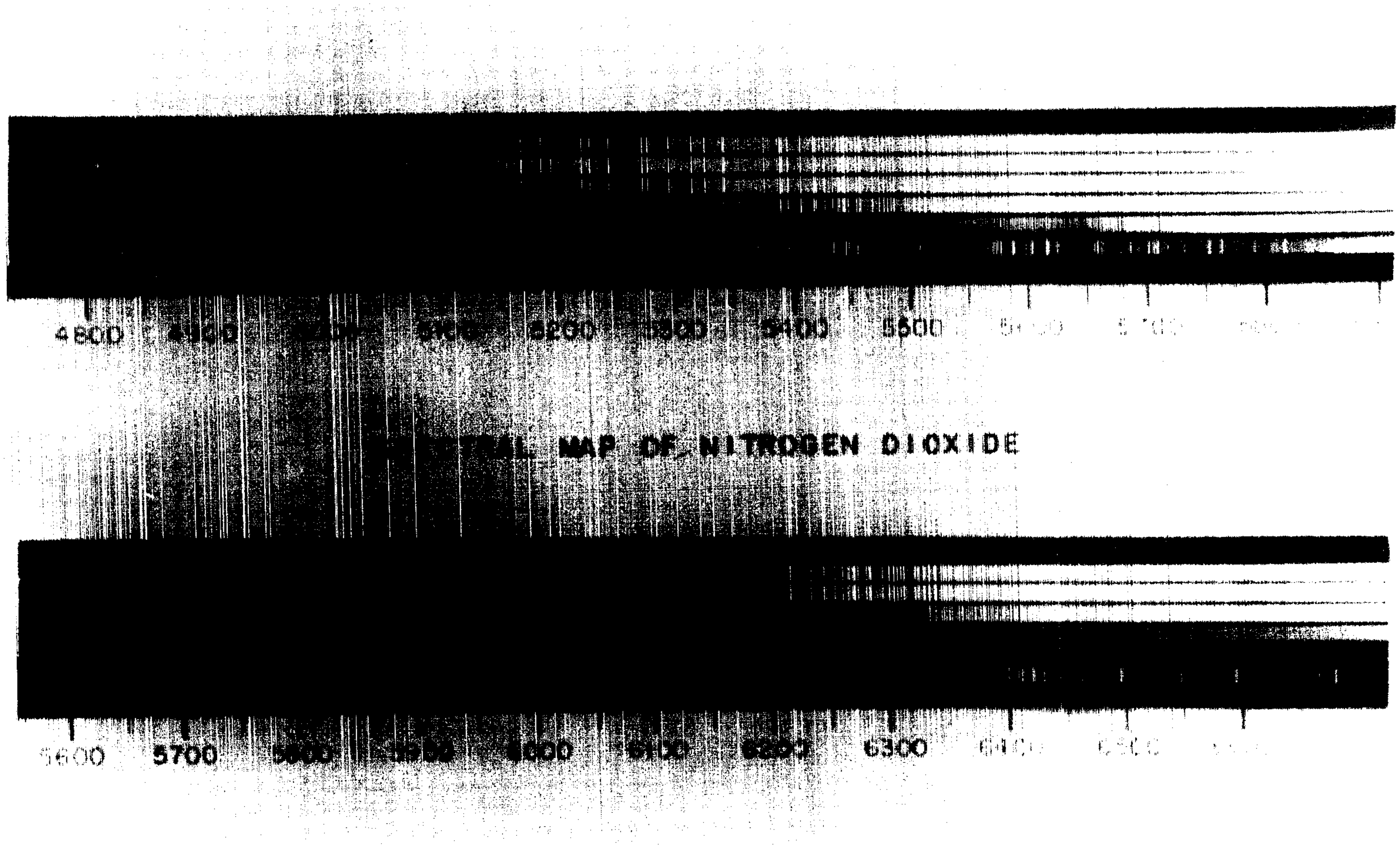
Plate No. 1



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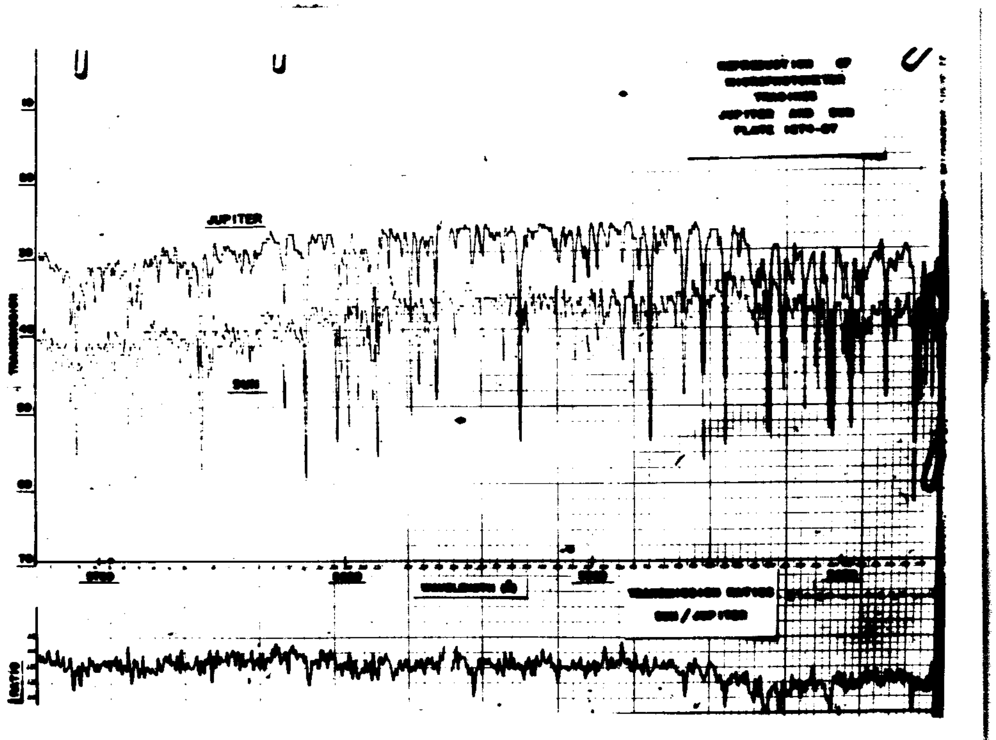


Figure 3

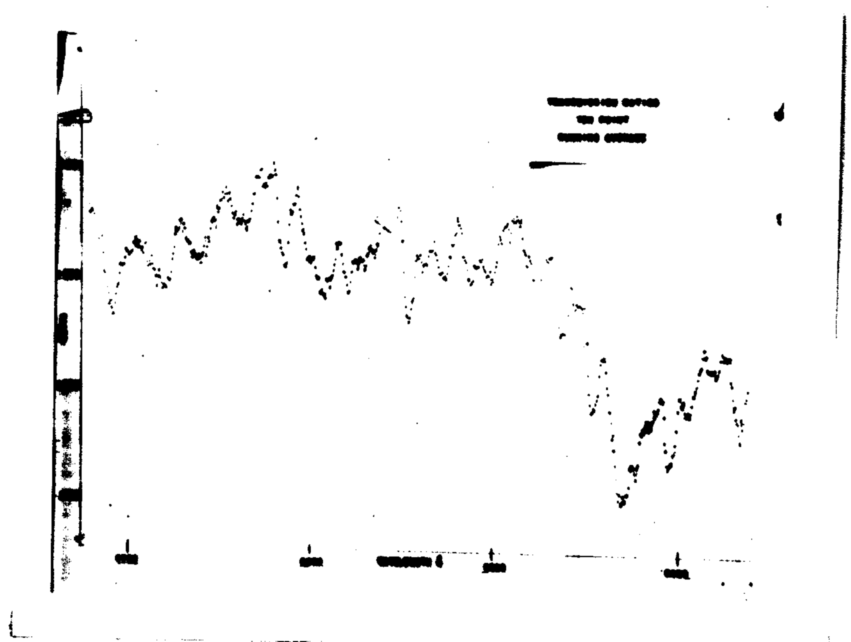
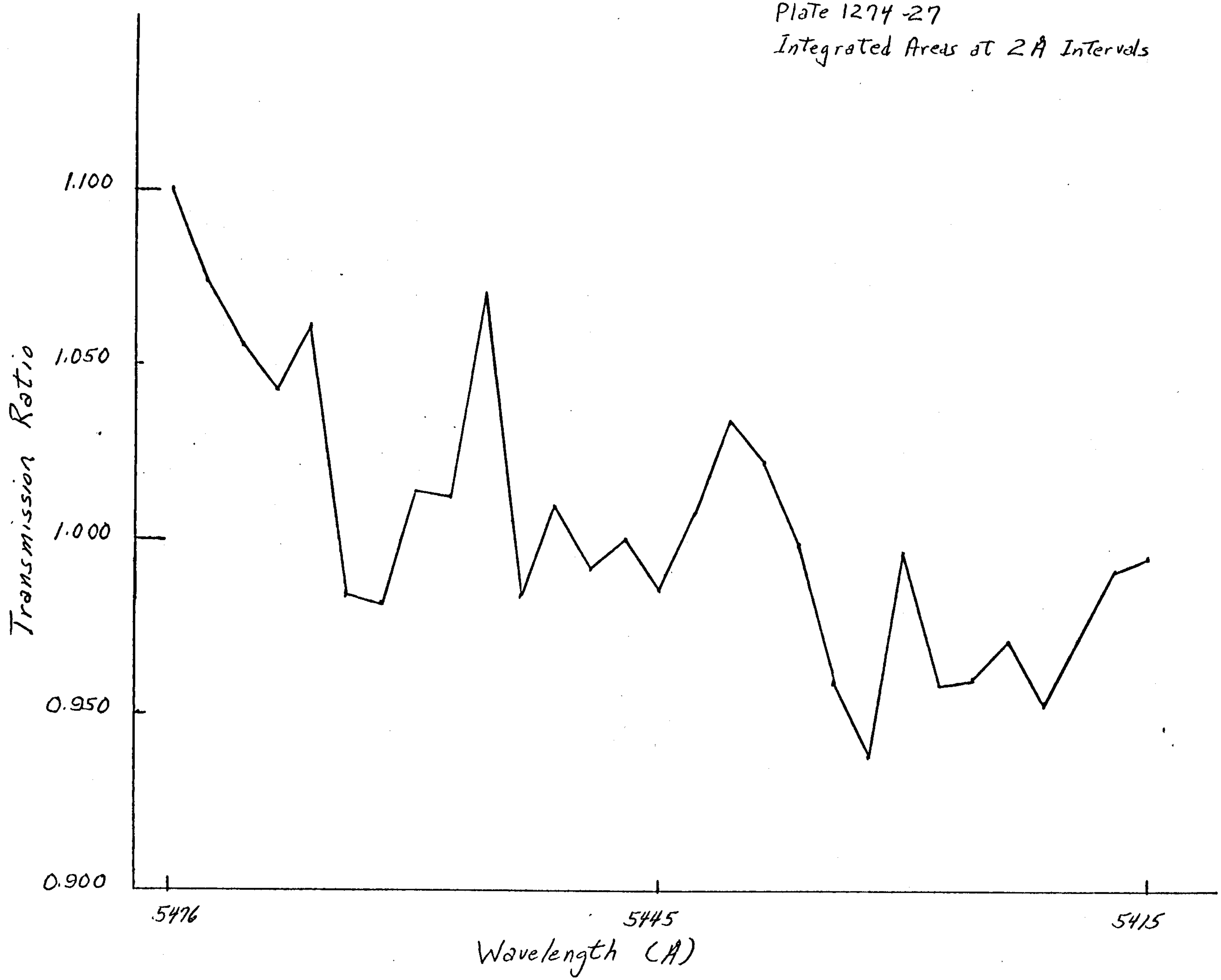


Figure 4

Figure 5
Transmission Ratio: Sun/Jupiter
Plate 1274-27
Integrated Areas at 2Å Intervals



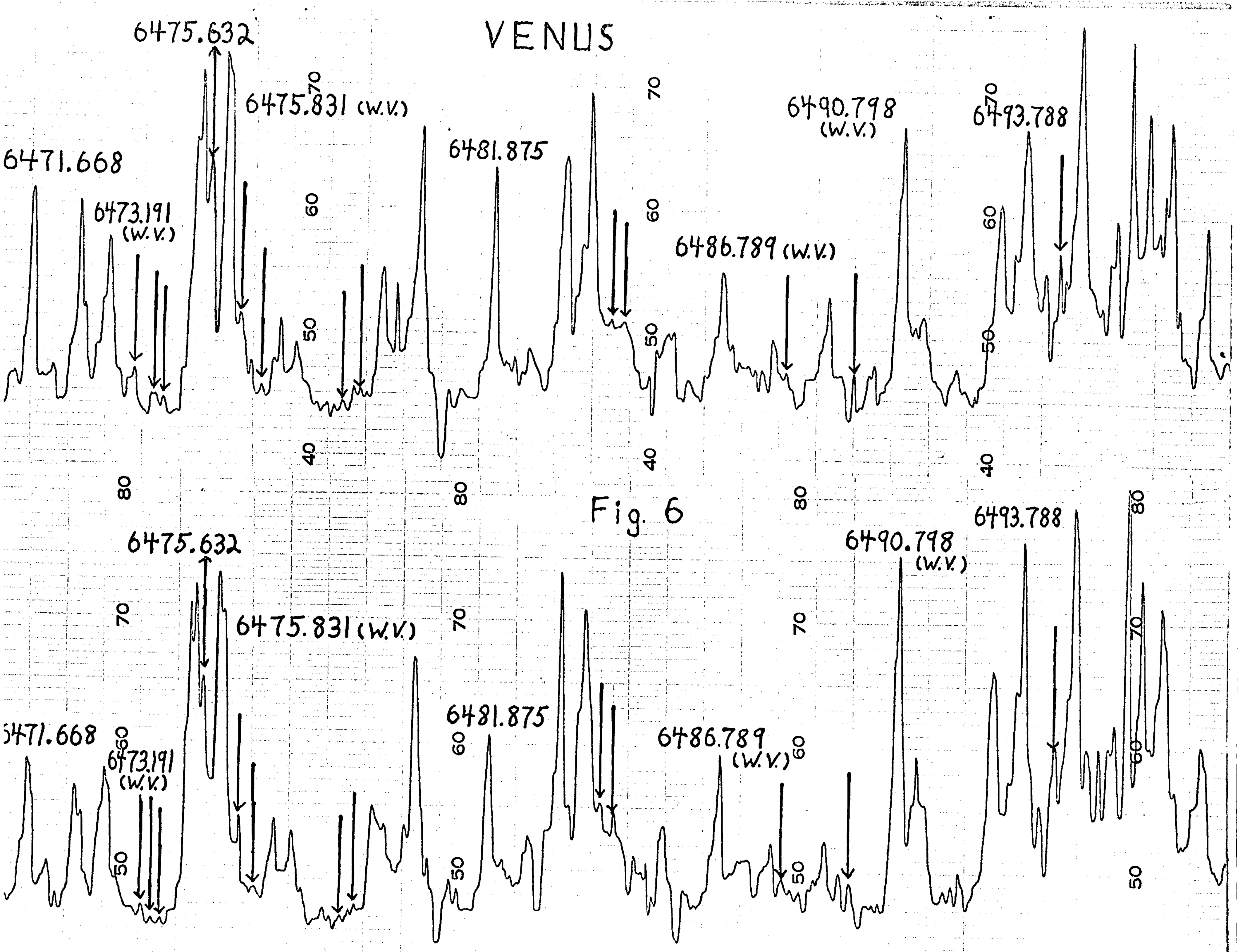

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Fig. 6

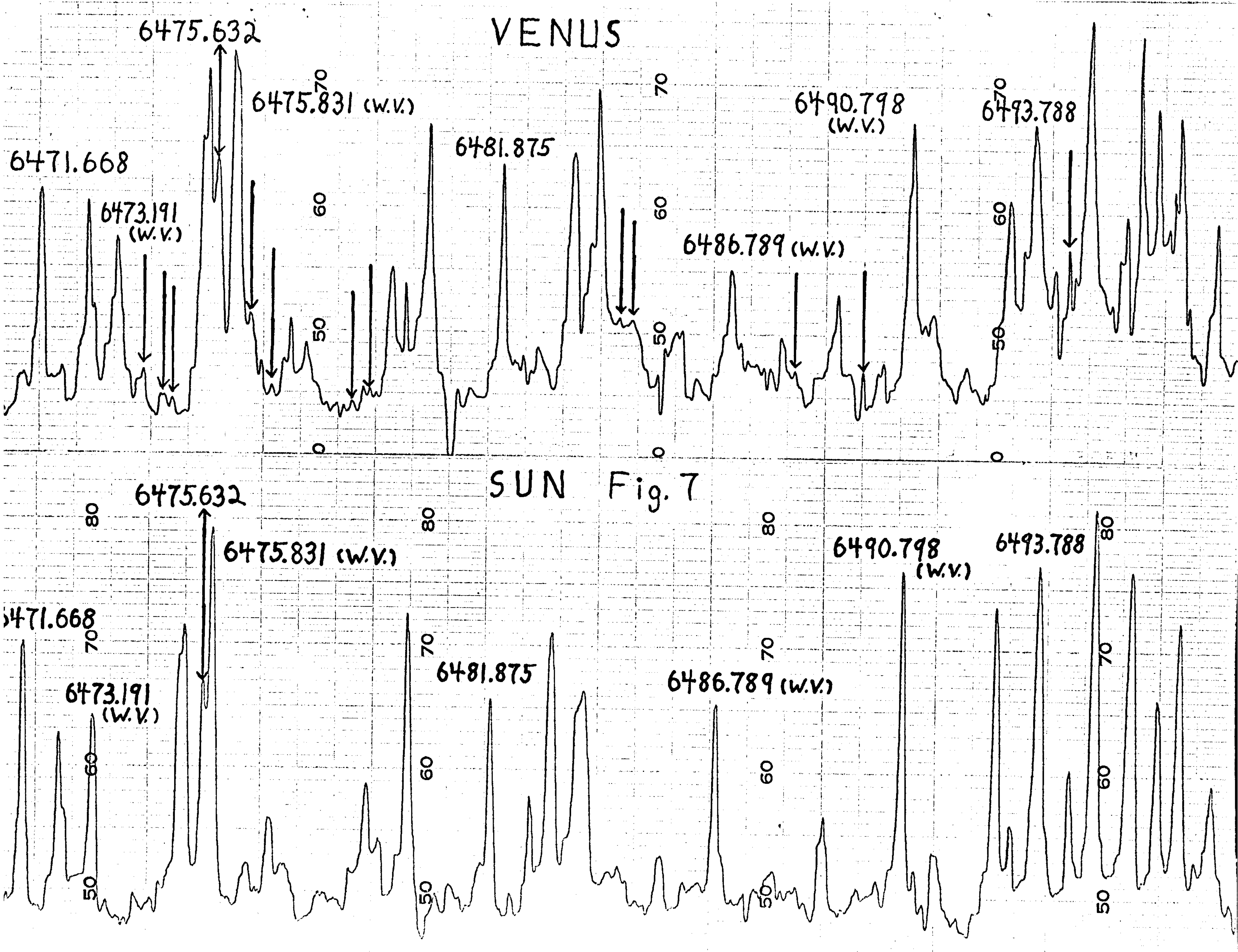
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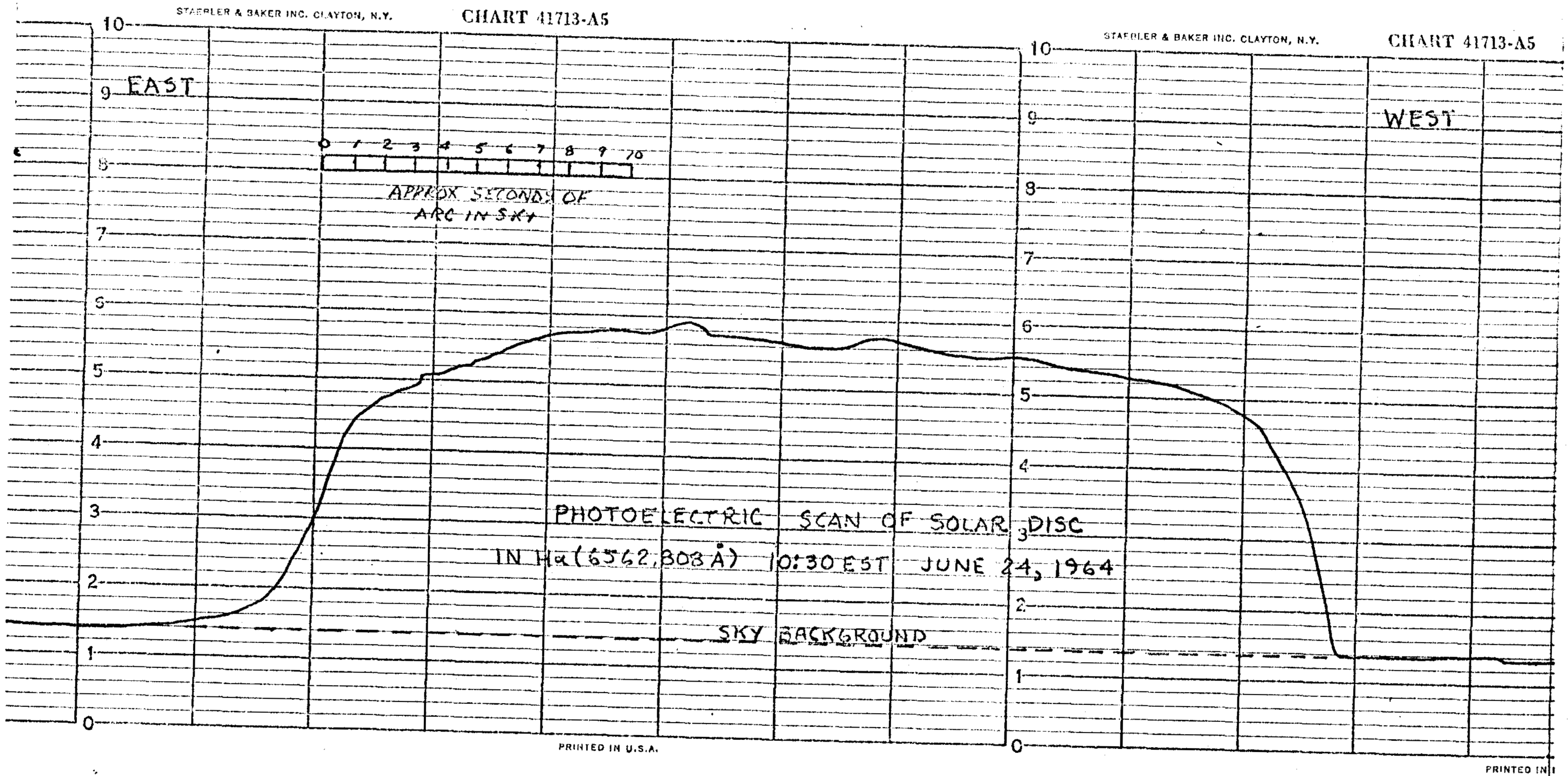
Fig. 7

Fig. 8



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